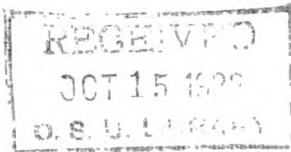


DEPARTMENT OF COMMERCE

UNITED STATES BUREAU OF MINES  
SCOTT TURNER, DIRECTOR

INFORMATION CIRCULAR



MINING METHODS AND COSTS AT THE  
INTERSTATE ZINC & LEAD CO.'S HARTLEY  
MINE, TRI-STATE ZINC AND LEAD DISTRICT



BY

CARL N. ANDERSON

INFORMATION CIRCULAR

DEPARTMENT OF COMMERCE - BUREAU OF MINES

---

MINING METHODS AND COSTS AT THE  
INTERSTATE ZINC & LEAD CO.'S HARTLEY MINE,  
TRI-STATE ZINC AND LEAD DISTRICT<sup>1</sup>

By Carl N. Anderson<sup>2</sup>

INTRODUCTION

This paper, which is one of a group presented by the United States Bureau of Mines covering mining practice in different districts, deals in particular with the methods employed in mining the horizontal type of zinc-lead orebodies of the West Baxter area of the Tri-State zinc and lead district. These orebodies, locally termed "sheet-ground" bodies, with their relatively low working faces and low tenor of zinc and lead, require changes in the mining practice which is used in the balance of the district. In addition to the general mining methods, this paper also describes the system of hand sorting employed prior to the direct milling of the ore.

The Hartley mine is situated  $\frac{1}{4}$  mile west of Baxter Springs, Kans., as indicated in Figure 1. Its general outline and the location of the shafts with respect to the milling plant are shown in Figure 2.

ACKNOWLEDGMENTS

The author acknowledges the helpful assistance and suggestions given him by C. F. Dike, general manager of the Interstate Zinc & Lead Co., George M. Fowler, mining geologist, Joplin, Mo., and Charles F. Jackson, mining engineer of the U. S. Bureau of Mines.

HISTORY

The sheet-ground ore deposit of the Hartley mine was indicated by churn drilling during the period 1919 to 1922. During this time a high-grade vertical-fracture orebody was being mined and little attention was given to the lower-grade deposit, which contained from  $4\frac{1}{2}$  to 5 per cent of zinc sulphide. With the depletion of the high-grade deposit, the low-grade area was further developed by churn drilling, which indicated an orebody of sufficient size and grade to warrant operations on a large scale. The milling plant was enlarged and rearranged so as to have a capacity of 135 tons per hour, and in February, 1929, the actual mining of the sheet-ground deposit was begun.

GEOLOGY

Figure 3, a vertical section on line A-A of Figure 4, shows the general geologic structure through the present mine workings. Figure 4 is a plan of the lower-level workings from shaft 6 and shaft 8. Soil and clay are found to a depth of 10 to 20 feet below the surface.

---

1 - The Bureau of Mines will welcome reprinting of this paper, provided the following footnote acknowledgment is used:  
"Reprinted from U. S. Bureau of Mines Information Circular 6656."

2 - One of the consulting engineers, U. S. Bureau of Mines, and superintendent, Hartley mine of the Interstate Zinc & Lead Co.

This is followed by a soft, dark shale, known as the Cherokee formation, having a thickness of 60 to 200 feet. Below the Cherokee shale comes the Boone formation, which is made up of a series of metamorphosed beds of limestone, many of them being of chert and flint. The zone of ore deposition that this paper has to deal with is at a depth of 290 to 310 feet below the surface. The mineralization is widespread and rather uniform, though richer areas are found where there has been an increase in the brecciation of the chert.

In the mining of this deposit there are three distinct beds of mineralization to be considered. The upper bed, called the O bed, has a thickness of 8 to 12 feet which as a rule is mineralized throughout so as to be classed as commercial ore. Below this there is a chert and flint stratum, known as the P bed. This has a thickness of 6 to 8 feet and is mineralized only at places where premineral brecciation and fracturing has taken place. This is followed by the Q bed, which has a thickness of 4 to 6 feet and is mineralized similarly to the upper or O bed. This lower bed is not of such a grade and thickness that it can be mined by itself, so that if the P bed is not mineralized to a commercial extent, the operations are confined to the upper or O bed. However, in localities where the intermediate or P bed is sufficiently mineralized, all three beds are mined. Slumpage of the overlying strata has in places caused brecciation and fracturing to extend upward for a hundred feet or more, and under certain conditions orebodies of the vertical-fracture type have been formed. In Figure 3 one such orebody is shown, the ore in this case extending in an irregular fashion to within 200 feet of the surface. Such deposits are, as a rule, much richer than the underlying bedded deposits. The ore in the bedded deposits consists of ribbons and pockets of sphalerite and galena between the flint and chert strata. Brecciation has had a vital influence on this type of deposit, and where brecciation is present the ore occurs as a cementing material between the particles of flint and chert. No faulting of any consequence has taken place and it is not unusual for individual strata to be traced for hundreds of feet. The upper and lower limits of the deposit dip and undulate slightly, but not to such an extent as seriously to handicap mining.

The ore-bearing beds are easily recognized because of the presence therein of nodules of chert and flint. The classification of the beds as shown on Figure 3 is one established by George M. Fowler of Joplin, Mo., and adopted at the Hartley mine to differentiate one bed from another. The classification of the Boone formation as it applies to the Tri-State district in general follows. This, together with information on the ore deposits of the Tri-State district, will be found in Technical Publication 446 of the American Institute of Mining and Metallurgical Engineers under the authorship of George M. Fowler and Joseph P. Lyden of Joplin, Mo.

#### Stratigraphic Section, Boone Formation

| Bed | Thickness, Ft.                    | Characteristics                                                                                                                                                                               |
|-----|-----------------------------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| B   | 0-125<br>(depending upon erosion) | Gray and brown limestone and dolomite.                                                                                                                                                        |
| C   | 25-32                             | Gray and brown limestone and dolomite. Blue, brown, and white flint. (Blue flint horizon near base.)                                                                                          |
| D   | 18-22                             | Nearly white limestone, dolomite, and flint. (Cotton rock horizon.)                                                                                                                           |
| E   | 6-8                               | Generally coarse, "sandy" dolomite or flint. An important ore bed in some mines. This bed is generally an important source of galena.                                                         |
| F   | 12-15                             | Limestone or flint. Generally barren.                                                                                                                                                         |
| G   | 8-13                              | An important ore horizon in a number of mines in the vicinity of Picher. Ore occurrences in this and H bed are generally similar, but this bed is richer. G and H are often mined as one bed. |

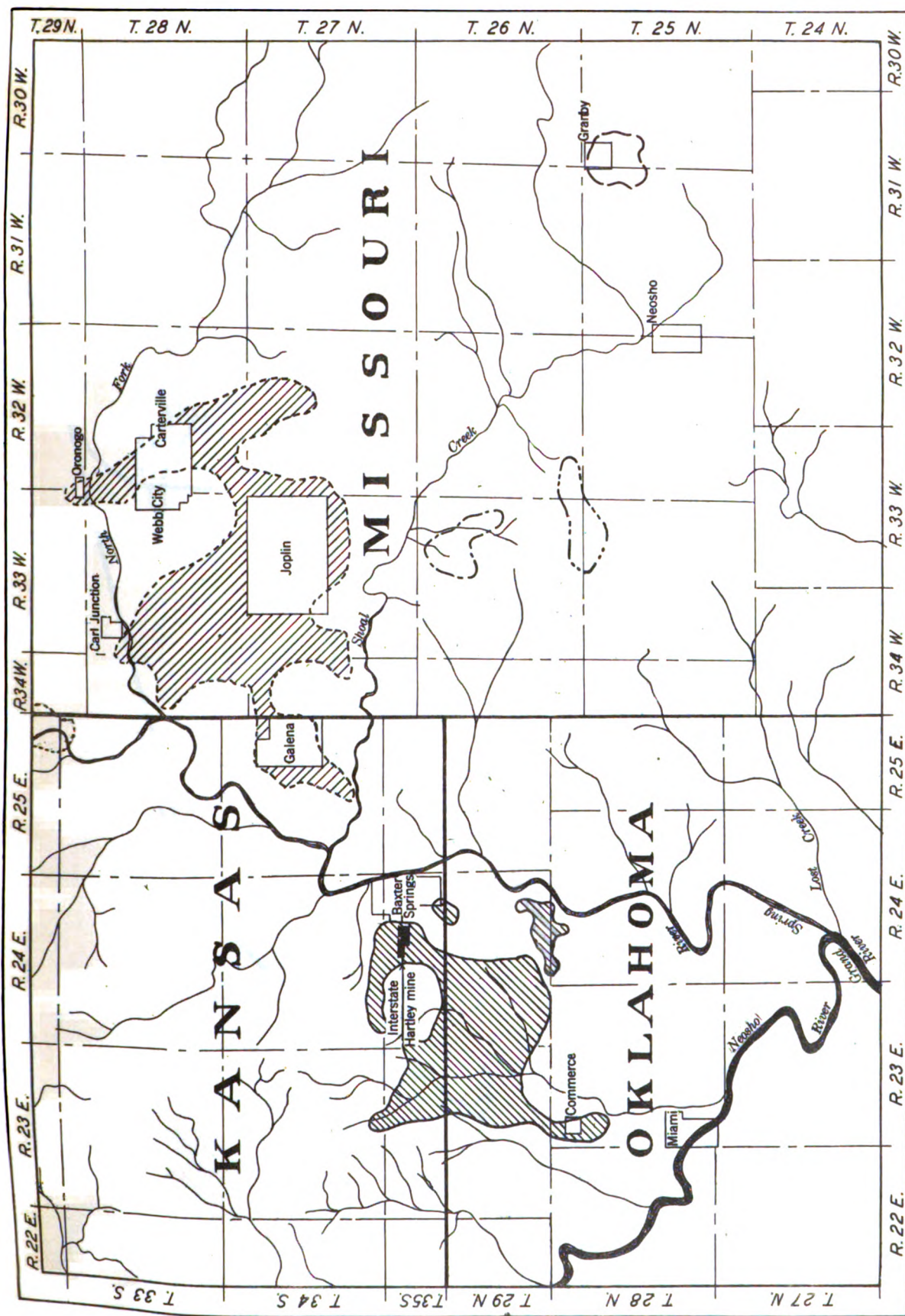


Figure 1.-- Central part of Tri-State zinc and lead district, showing location of Hartley mine

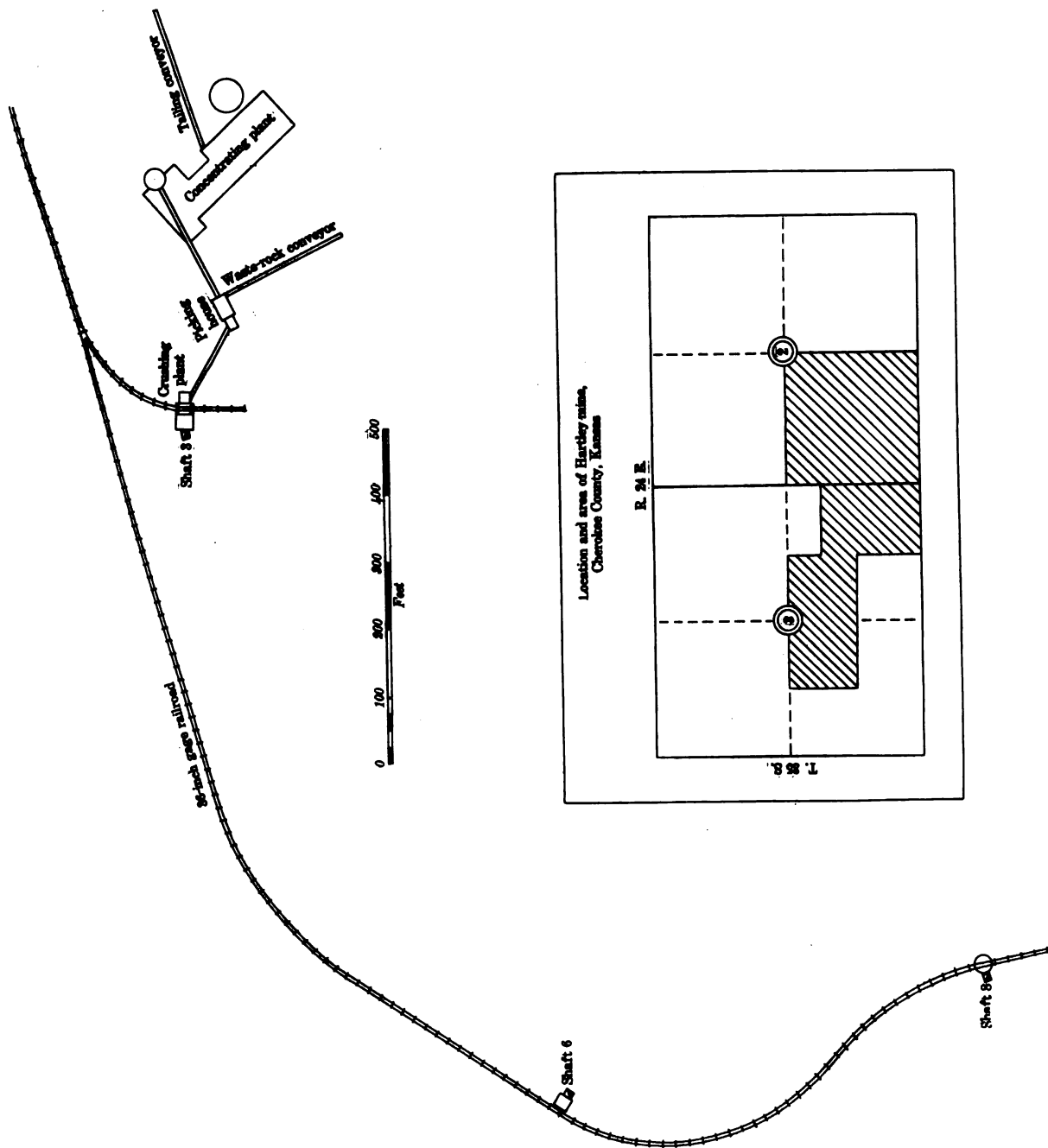


Figure 2.- Outline of Hartley mine and location of shafts with respect to the milling plant

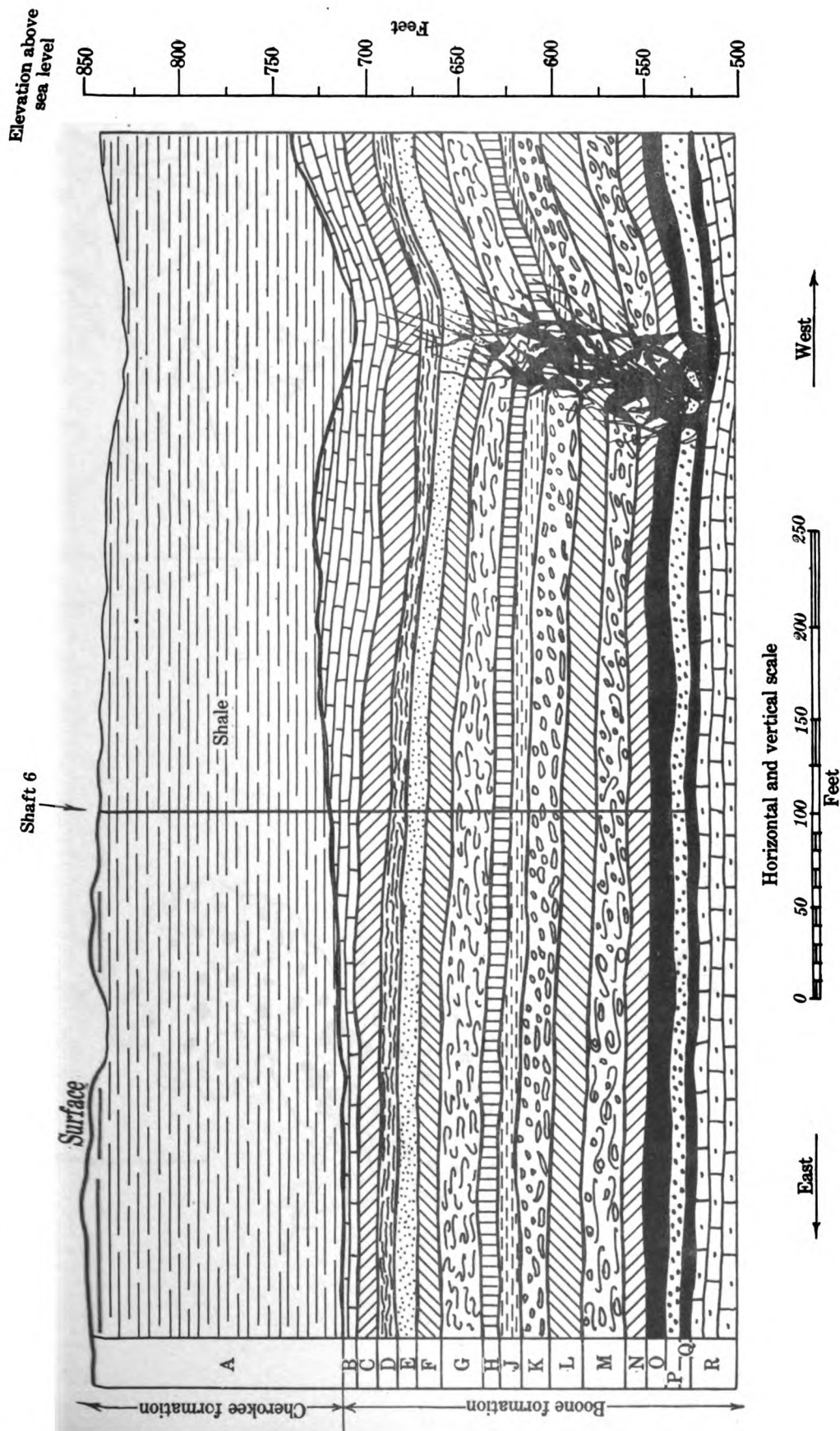


Figure 3.- Vertical section on line A-A' of Figure 4, showing general geology

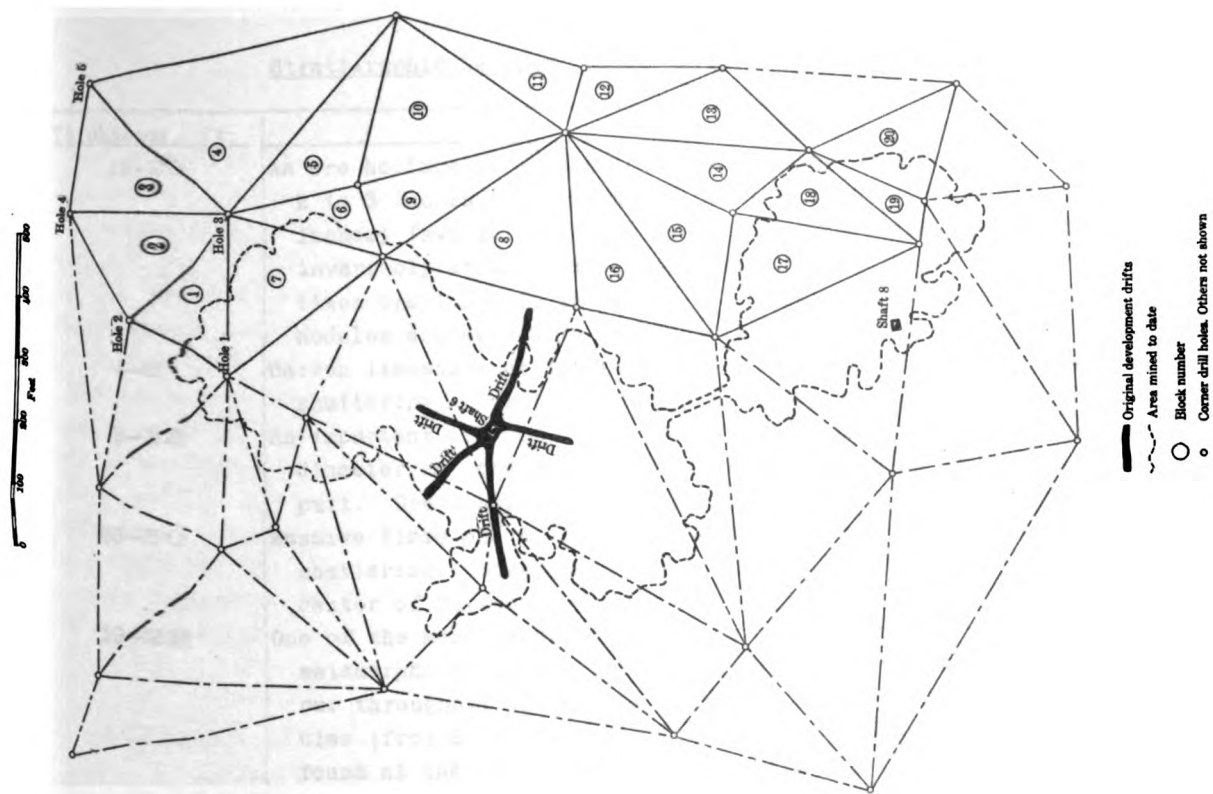


Figure 5.- Ore-reserve map

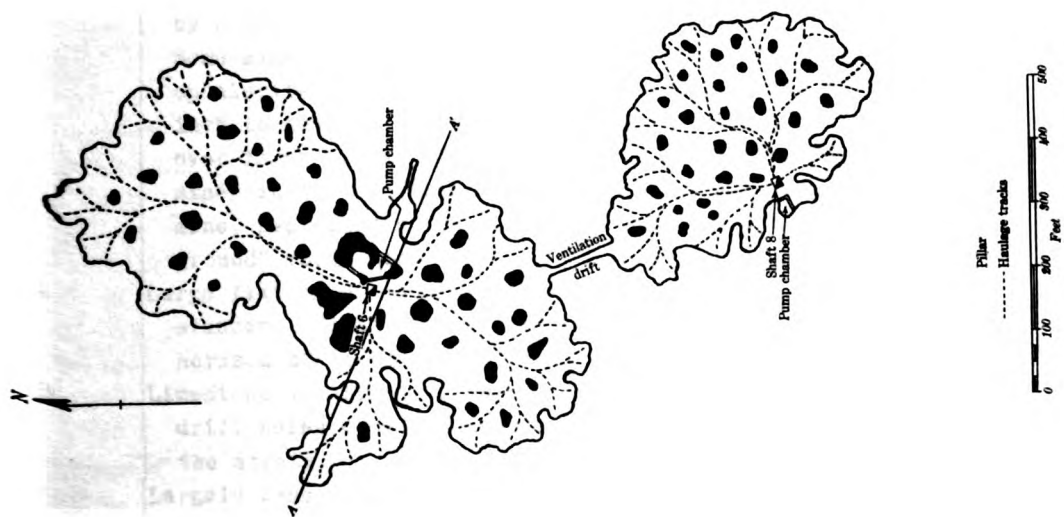


Figure 4.- Plan of lower-level workings, shafts 6 and 8

Stratigraphic Section, Boone Formation-Continued

| Bed            | Thickness, Ft. | Characteristics                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                            |
|----------------|----------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| H              | 15-20          | An ore horizon in some mines. Thin-bedded limestone or cherty bands 2 to 5 inches thick with the ore gradually replacing thin ( $\frac{1}{4}$ to 2 inches) favorable strata. This stratified mineralization almost invariably occurs with banded galena above the sphalerite. Sometimes ore found is in an 8 to 10 foot stratum directly above J. Nodules are generally absent in beds F, G and H.                                                                                                                                                         |
| J              | 4-8            | Barren limestone or flint. Mineralized only in areas of intense shattering. Sometimes occurs as soft, greenish, limy stratum.                                                                                                                                                                                                                                                                                                                                                                                                                              |
| K              | 8-12           | An important ore bed. Comprises rounded nodules 5 to 9 inches in diameter in upper part of bed with long larger nodules in lower part. Ore generally confined to the upper two-thirds of bed.                                                                                                                                                                                                                                                                                                                                                              |
| L              | 26-30          | Massive limestone or flint. Contains ore only in zones of intense shattering. Sometimes a 5-foot stratum of oolite is found near the center of horizon.                                                                                                                                                                                                                                                                                                                                                                                                    |
| M              | 19-22          | One of the most important ore beds of the Picher-Miami area. Where metamorphosed, definite nodules from 4 to 12 inches in diameter occur throughout the entire thickness of the bed. Often large nodules (from 6 to 12 inches thick by 2 to 5 feet in diameter) are found at the bottom of the bed. This bed as mined in different parts of the Picher-Miami area varies in thickness from 5 to 22 feet. The bottom 12 feet is the most productive horizon.                                                                                                |
| N              | 10-20          | Massive limestone, dolomite, or flint with very few large (1 foot thick by 5 to 15 feet in diameter) nodules. In some mines a "porcelain" stratum 1 foot thick is found 6 to 8 feet from the top of the bed.                                                                                                                                                                                                                                                                                                                                               |
| O <sup>1</sup> | 8-9            | Important ore bed in a few mines. Round flat nodules (2 to 4 inches by 3 to 6 feet) embedded with cherty bands 1 to 4 inches thick. Some mines contain interbedded layers of nearly pure galena or sphalerite, or both, varying in thickness from a fraction of an inch to several inches. These sheets of ore often are persistent over large areas. Such mineralization comprised the "sheet ground" mines in the old Missouri fields. The southern part of the See-Sah mine, near Cardin, Okla., is in this bed and is in the "sheet-ground" formation. |
| P <sup>1</sup> | 8-11           | Large flat chert nodules interbedded in chert. Barren in most instances. Sometimes mineralized, with beds O, P and Q making an ore horizon 30 to 38 feet-thick.                                                                                                                                                                                                                                                                                                                                                                                            |
| Q <sup>1</sup> | 17-18          | Limestone and flint, generally massive. Only a relatively few churn-drill holes have reached depths greater than 50 feet below Q bed of the strata.                                                                                                                                                                                                                                                                                                                                                                                                        |
| R              | 55             | Largely dense limestone or dolomite with few chert nodules. The Riverside mine on Shoal Creek near Joplin is in this horizon.                                                                                                                                                                                                                                                                                                                                                                                                                              |

1 - The Grand Falls horizon described by Smith and Siebenthal has not been determined definitely. Apparently it falls within the range of beds O, P, and Q, as described.

Exploration and Development

The initial exploration of this property, as mentioned, was by churn drilling. During this operation, samples of the material penetrated by the drill are taken at 5-foot intervals while drilling through the overlying strata. Upon reaching the ore horizon, samples are taken at 2½-foot intervals. These are carefully panned and if sufficient mineral showing is obtained, are assayed for zinc and lead. Careful logs are made of all holes, and it is from these records that the general structure maps and tonnage calculations are obtained.

Figure 5 is an ore-reserve map which shows a portion of the Hartley sheet-ground area with the location of drill holes and the method used in calculating the drilled-out tonnage. The area mined to date is shown by the dotted lines. The tonnage and grade of ore removed from this area compare very closely with the tonnage and grade indicated by the triangle calculations. The method of calculation involves cutting the area up into a number of triangles, each having its corner at a drill-hole location. The average thickness of ore as indicated by these three corner holes, and the area of the triangle gives the data for calculating the tonnage. The average tenor of zinc and lead in the three corner holes, together with that of any that may have been drilled within the triangle, is taken to represent the tenor of the block enclosed by the triangle. As an illustration, there follow the data on 20 of the triangles shown on Figure 5.

Ore face (feet) and grade indicated by drill holes 1 to 5, inclusive

| Hole No. | From | To   | Feet | ZnS, per cent | Feet x per cent ZnS |
|----------|------|------|------|---------------|---------------------|
| 1        | 291  | 293  | 2    | 3.33          | 6.66                |
|          | 293  | 296  | 3    | 8.50          | 25.50               |
|          | 296  | 298  | 2    | 3.67          | 7.34                |
|          | 298  | 300  | 2    | 7.33          | 14.66               |
|          |      |      | 9    |               | 54.16               |
| 2        | 287  | 292  | 5    | 4.14          | 20.70               |
|          | 292  | 295  | 3    | 0.90          | 2.70                |
|          | 295  | 297½ | 2½   | 1.89          | 4.72                |
|          | 297½ | 300  | 2½   | 3.48          | 8.70                |
|          |      |      | 13   |               | 36.82               |
| 3        | 290  | 295  | 5    | 3.60          | 18.00               |
|          | 295  | 297½ | 2½   | 1.53          | 3.82                |
|          | 297½ | 300  | 2½   | 2.07          | 5.17                |
|          | 300  | 302½ | 2½   | 6.99          | 17.47               |
|          | 302½ | 305  | 2½   | 8.91          | 22.27               |
|          | 305  | 307½ | 2½   | 7.14          | 17.85               |
|          |      |      | 17½  |               | 84.58               |
| 4        | 295  | 300  | 5    | 1.08          | 5.40                |
|          | 300  | 305  | 5    | 4.44          | 22.20               |
|          |      |      | 10   |               | 27.60               |
| 5        | 290  | 292½ | 2½   | 2.49          | 6.22                |
|          | 292½ | 295  | 2½   | 1.14          | 2.85                |
|          | 295  | 297½ | 2½   | 2.16          | 5.40                |
|          | 297½ | 300  | 2½   | 13.05         | 32.62               |
|          | 300  | 302½ | 2½   | 11.04         | 27.60               |
|          |      |      | 12½  |               | 74.69               |

The foregoing holes form the corners of triangles 1, 2, and 3.

Triangle 1

| <u>Corner holes</u> | <u>Feet</u> | <u>Feet x. per. cent ZnS</u> |
|---------------------|-------------|------------------------------|
| 1                   | 9           | 54.16                        |
| 2                   | 13          | 36.82                        |
| 3                   | <u>17½</u>  | <u>84.58</u>                 |
|                     | 39½         | 175.56                       |

Average ore face equals  $39\frac{1}{2} / 3$ , or 13 feet.

Average ZnS tenor equals  $175.56 / 39.5$ , or 4.44 per cent.

Triangle 2

| <u>Corner holes</u> | <u>Feet</u> | <u>Feet x. per. cent ZnS</u> |
|---------------------|-------------|------------------------------|
| 2                   | 13          | 36.82                        |
| 3                   | 17½         | 84.58                        |
| 4                   | <u>10</u>   | <u>27.60</u>                 |
|                     | 40½         | 149.00                       |

Average ore face equals  $40.5 / 3$ , or 13.3 feet.

Average ZnS tenor equals  $149.00 / 40.5$ , or 3.67 per cent.

Triangle 3

| <u>Corner holes</u> | <u>Feet</u> | <u>Feet x. per. cent ZnS</u> |
|---------------------|-------------|------------------------------|
| 3                   | 17½         | 84.58                        |
| 4                   | 10          | 27.60                        |
| 5                   | <u>12½</u>  | <u>74.69</u>                 |
|                     | 40          | 186.87                       |

Average ore face equals  $40 / 3$  or 13.3 feet.

Average ZnS tenor equals  $186.87 / 40$  or 4.67 per cent.

The following table shows the calculation of tonnages from the triangle areas and height of ore faces, together with the ZnS in each as determined by the method just described.

Churn drilling is for the most part done by contract. The contractors own the drill rigs and do the work for a certain charge per foot of hole. This charge varies according to the character of the formation being drilled and runs from \$0.90 to \$1.25 per foot. On the Hartley property, which consists of 320 acres, a total of 423 holes has been drilled with a total footage of 115,173. The item of churn drilling constitutes the largest part of these costs which go toward the prospecting and development of a mine in the Tri-State district. Large expenditures are often made on numerous tracts of land before an orebody of commercial value is found. It is also not unusual for several mining companies to follow one another in drilling and abandoning a tract of land before the orebody is finally located. The records of a number of mining companies operating in Cherokee County, Kans., show that during the past 12 years a total of \$4,473,300 was spent in the churn drilling of 16,281 prospect holes. Of this number 9,591 were on tracts which became producing mines, while the balance were drilled on areas that were abandoned.

Tonnages calculated from triangle area and height of ore face, and ZnS content

| Block No. | Triangle<br>base, feet | Triangle<br>height, feet | Ore<br>face, feet | Cubic feet | Tons<br>(13 cu.ft. per ton) | Average<br>per cent of ZnS |
|-----------|------------------------|--------------------------|-------------------|------------|-----------------------------|----------------------------|
| 1         | 258                    | 125                      | 13                | 209,625    | 16,125                      | 4.44                       |
| 2         | 245                    | 187                      | 13                | 297,791    | 22,907                      | 3.67                       |
| 3         | 302                    | 182                      | 13                | 357,266    | 27,482                      | 4.67                       |
| 4         | 512                    | 242                      | 12                | 743,424    | 57,186                      | 4.81                       |
| 5         | 410                    | 125                      | 12                | 307,500    | 23,653                      | 4.54                       |
| 6         | 255                    | 95                       | 14                | 169,568    | 13,043                      | 4.71                       |
| 7         | 255                    | 250                      | 13                | 414,375    | 31,875                      | 3.96                       |
| 8         | 347                    | 236                      | 13                | 532,298    | 40,946                      | 4.85                       |
| 9         | 338                    | 120                      | 12                | 243,360    | 18,720                      | 4.97                       |
| 10        | 320                    | 260                      | 9                 | 374,400    | 28,800                      | 4.83                       |
| 11        | 320                    | 95                       | 10                | 152,000    | 11,692                      | 5.10                       |
| 12        | 272                    | 86                       | 13                | 152,048    | 11,696                      | 3.81                       |
| 13        | 272                    | 125                      | 16                | 272,000    | 20,923                      | 3.47                       |
| 14        | 375                    | 102                      | 15                | 286,875    | 22,067                      | 4.52                       |
| 15        | 400                    | 140                      | 11                | 308,000    | 23,692                      | 6.29                       |
| 16        | 400                    | 150                      | 12                | 360,000    | 27,692                      | 5.73                       |
| 17        | 360                    | 168                      | 12                | 362,880    | 27,913                      | 5.70                       |
| 18        | 302                    | 112                      | 16                | 270,592    | 20,814                      | 4.25                       |
| 19        | 230                    | 60                       | 16                | 110,400    | 8,500                       | 3.82                       |
| 20        | 370                    | 128                      | 18                | 426,240    | 32,787                      | 3.08                       |

The first development of the sheet-ground deposit of the Hartley mine, after the drilling campaign, consisted in the sinking of shaft 6, and the driving of drifts in the ore as shown in Figure 5. The shaft has a cross section of 6 by 9 feet and is cribbed through the shale horizon with 2 by 6 inch timbers, laid flat. The drifts, which were driven on the lower limit of the orebody, were 5 by 7 feet in cross section. From these drifts, numerous small raises were extended to the upper limit of the ore. All of the material resulting from the driving of these drifts and raises was then milled, thereby giving a check on the drill-hole data. The results being favorable, the mining of the orebody was started, and since then no development work has been done aside from additional shaft sinking and a small amount of drilling. In shaft sinking, a small derrick and hoist is generally used, which upon reaching the ore horizon is replaced by the standard operating unit. The cost of sinking and equipping the average shaft amounts to about \$10,000.

## MINING METHODS

Figure 4 shows a plan of the mine workings, and the room-and-pillar method of cutting the ground is at once recognized. The ore beds, as well as the overlying strata, are of such character as to be self supporting over spans of from 30 to 60 feet. Supporting pillars of ore are spaced on an average of 40 feet from edge to edge and vary in diameter from 20 to 30 feet. In the course of mining, care must be exercised not to break into the overhead flint strata that is being carried as the roof. If this strata is broken, it tends to slack and peel down in slabs which often extend from pillar to pillar. This not only dilutes the material broken from the ore horizon, but constitutes an element of danger for the workmen. Serious accidents frequently occur in this district from the slabbing down of the roof strata.

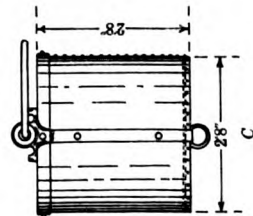
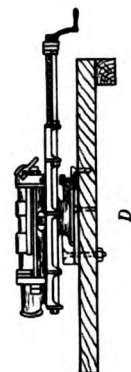
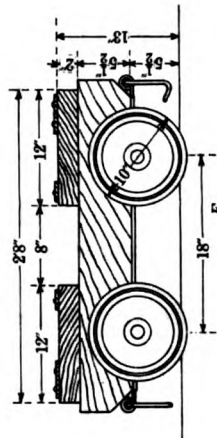
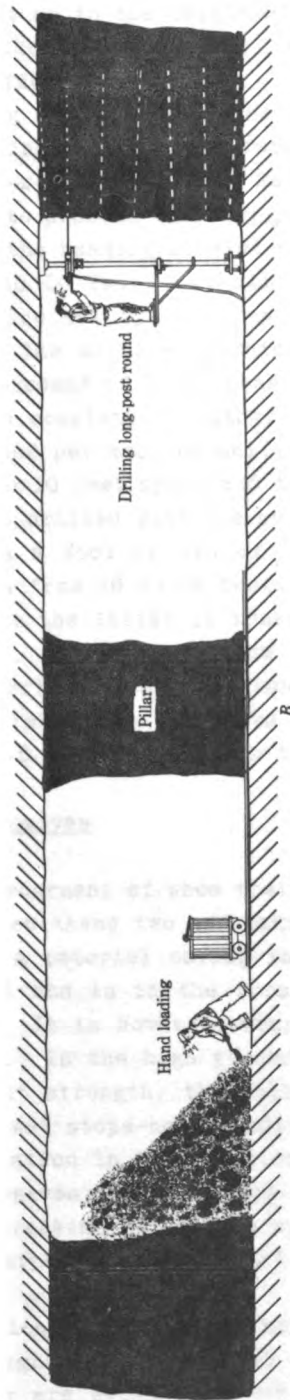
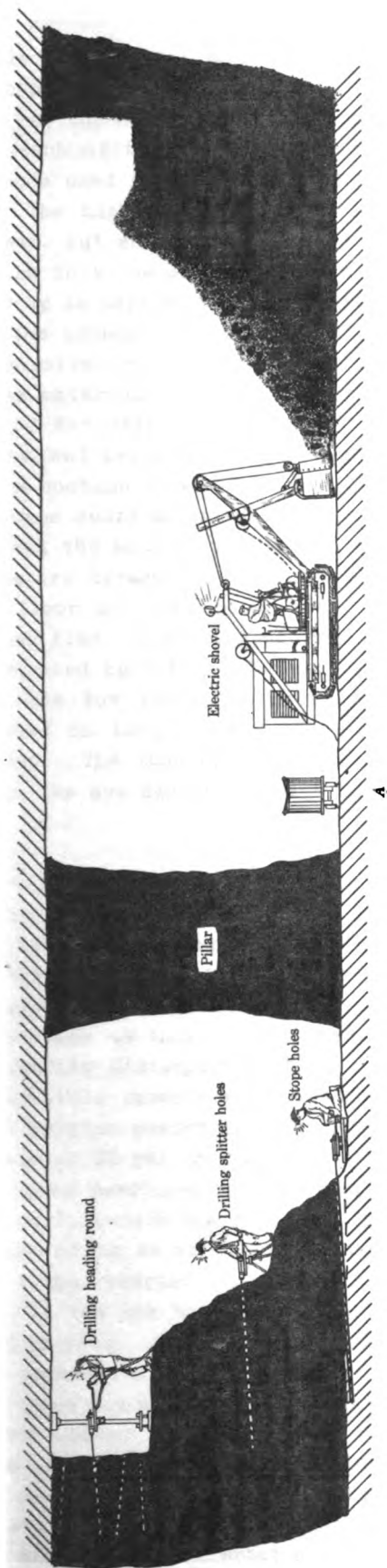


Figure 6.- Mining methods and equipment: A, High ground, No. 6 workings; B, low ground, No. 8 workings; C, ore tub; D, drill mounted on stope board; E, mine car

Falls come without warning and the only safeguard is to blast or pry down any roof that has been broken into.

At the Hartley mine two conditions exist as to the height of ore face that can be mined and each of these calls for a different method of operation. Figure 6 shows the general methods used in mining the high and the low faces.

The high faces are mined by the heading and stope-hole method (fig. 6-a). The upper 7 feet, cut so as to be in advance of the balance of the ore face, is termed the "heading," and in this the drilling is done with column-mounted drills. Between pillar locations this heading is carried in a zigzag fashion so as to present the best possible breaking conditions for the rounds drilled. The drill rounds in the heading consist of six to eight holes drilled parallel to the offset, to depths of 8 to 10 feet. At all locations of drilling, the loose material is cleared away for the machine set up, the day before, by men who are employed for this purpose only. This permits the machine operator and helper to set up the column and begin drilling without delay. One round of holes does not constitute a days work for a machine crew. When one round has been completed, another is started, and an average of seven hours actual drilling time is obtained per machine shift. Midway between the heading and the mine floor, holes are drilled 8 to 10 feet apart and to a depth of 12 to 14 feet. These are termed the "splitter holes" and are drilled with the machine mounted on a tripod. The floor or stope holes are drilled within a foot or two of the mine floor and are run rather flat. The depth of these holes varies from 16 to 18 feet. The machine in this case is mounted on either a tripod or stope-board; the latter is shown in Figure 6 at d.

The low faces, as shown in Figure 6-b, are drilled from top to bottom by machines mounted on long columns, the face being carried in zigzag fashion just as in the higher ground. The tons of ore broken per machine shift by these two systems is very nearly the same, the average in the high faces being 72.5 tons and that in the low faces 71.0 tons.

### Explosives

All loading of explosives is done by powdermen, of whom there is one each for the high and low ground. One helper alternates between these two and makes up the primers. Tamping is used in all holes and its use has shown a material saving in explosives. This tamping is made from the tailing sludge of the mill and is in the form of cartridges of the same dimensions as those of the explosives used. It is however, wrapped in red paper, so as to be readily distinguished from the explosive. In the high ground the holes are loaded with permissible ammonia explosives of 40 per cent strength, the detonating charge being 35 per cent gelatin powder with No. 6 caps. Under wet stope-hole conditions the load consists entirely of 35 per cent gelatin. Since ventilation in this section of the mine is very good, the gases developed by the ammonia-base explosives are fully expelled by the time the following shift enters the mine. In dense, hard-breaking ground the splitter and stope holes are chambered so as to receive heavy bottom charges, but it is not often that this expedient has to be resorted to.

In the low headings where the ventilation is poorer the holes are loaded with 35 per cent gelatin. Single-tape fuse is used throughout the mine, and under wet conditions rubber cap protectors are used. All priming shots are encased in heavy cardboard safety tubes. The tubes are so constructed that in placing the primer in the drill hole it can not come in direct contact with either the rock or the tamping stick. These safety tubes are employed by a number of mines in this district, and there is no question that their use has cut down the number of premature explosions which have been quite numerous in the past. All of the primers are made up in a building on the surface and only the required number are taken into the mine each day. About a 2-day supply of explosives is kept in the mine and is stored in

an isolated drift where "Danger" and "No smoking" signs are conspicuously posted. At the end of each shift the machine operators and helpers light the shots for the rounds that they drilled the day before. The fuses are of such length that the men have ample time to reach the surface before any detonations take place.

### Power and Hand Shoveling

All underground loading is done into round sheet-steel cans which are 32 inches in diameter, 32 inches deep, and hold an average of 1,400 pounds each (fig. 6-c). Each can is transported to and from the shaft station on a low flat car (fig. 6-e).

In the low ground all of the loading is done by hand, the shovelers working on a contract basis and using No. 2 scoop shovels. The average loading ability of the Tri-State shoveler is 35 tons per 8-hour shift. Each shoveler works on an individual track, which is laid as close to the pile of broken ore as possible. He receives his empty cans at a conveniently located siding and places the loaded ones on the main haulage track. Each shoveler supplies himself with a number of wooden paddles, marked with a numeral assigned to him by the mine foreman. In each can, loaded by him, he places one of these markers and as the loaded cans arrive at the shaft station, the markers are placed in pigeon holes of corresponding numbers. At the end of the shift, the markers are counted by the mine foreman and each shoveler given credit for his work. A count is also made at the surface of all cans hoisted, and this acts as a check on the count at the underground shaft station. This method is very simple, and it is surprising how few errors occur.

In the high ground, both hand and power shovel loading is employed. Hand-loading conditions are the same as in the low ground, except that two men shovel into a can where the pile of broken material is large.

The Tri-State district has for a long time been the scene of experimentation with power shovels and mechanical loading devices. Very few of the various machines tried out have proved to be economical, with the result that mechanical loading is employed in only a few mines at this time. The power shovels used at the Hartley mine were developed at this property and have been found to fit into the operating program with a substantial saving in the cost of loading. When the question of power loading came up, the desire was to obtain a shovel that was mobile, electrically operated, fast, and of comparatively low cost. The machine that was adopted was developed from a light surface shovel of the boom and dipper stick type that was already on the market (fig. 6-a). For surface use this shovel was powered by a gasoline engine. As this engine could not be used in the mine, it was replaced by a 15-hp. electric motor which was connected to the drive shaft with a silent-chain drive. Other changes in the surface-type machine were made, such as cutting down the length of boom and dipper stick and reducing the ground clearance. A new type of dipper was designed for loading into the round cans, and electrical devices were added so that the operator would have perfect control of the mechanism. This shovel as developed for underground use is operated by one man, is rapid both as to mobility and action, and can be operated in a 9-foot room. It has ample power to clear away boulders weighing several tons and so far has proved economical both as to upkeep and operation.

The costs per ton of loading with a power shovel of this type compared with the costs of hand shoveling follow:

Power shovel

Period: 127 working days

Material loaded: 24,516 cans (16,565 tons)

|                                                            | <u>Cents</u> |
|------------------------------------------------------------|--------------|
| Connected energy charge.....                               | 0.382        |
| Power consumed.....                                        | .946         |
| Depreciation and repairs.....                              | 3.070        |
| Interest charge.....                                       | .776         |
| Labor (one operator with helper<br>and extra trammer)..... | <u>7.830</u> |
| Total cost per ton.....                                    | 13.004       |

Hand shovelers

|                         | <u>Cents</u> |
|-------------------------|--------------|
| Contract price.....     | 21.202       |
| Shovels and picks.....  | <u>.167</u>  |
| Total cost per ton..... | 21.369       |

Underground Haulage

All underground tracks are 18-inch gage and of 12-pound rails. Tracks are run into each heading and at the loading points are spaced 12 feet apart. Figure 4 shows in a general way the system of trackage used. The loaded cans are hauled from the gathering lay-bys to the shaft station by mules, each animal being able to handle from 8 to 15 loads. Up to the present, the hauls have not been of sufficient length to warrant the use of underground haulage motors, several types of which are employed in many of the mines of the district.

At the shaft station, the loaded cans are fed to a spot directly under the shaft center, by men known as "bumpers." These men, one on each side of the shaft, alternately push a loaded can (on its car) into position under the shaft. A man known as a "tub hooker" engages the cable hook and the bail of the can and the load is at once on its way to the surface. The hoist operator discharges the cans into the hopper by inserting a hook, on a tail rope, into a ring in the bottom of the can and slacking off a few feet of the hoist cable. This causes the can to swing away from the shaft, at the same time turning it over and discharging its contents. A trapdoor lying on an angle of 45° is closed over the shaft opening during this operation to keep any spillage from going back down the shaft.

As soon as the loaded can has left the car, the tub hooker rolls the empty can that has just returned onto this car and the bumper pushes it to the empty lay-by. By the time an empty can reaches the shaft bottom, a loaded one is in position ready for hoisting. As the empty can nears the shaft bottom, the hooker pulls it to one side and rests it on his working platform while he changes the hook to the loaded one. These men become skilled in this work, and the speed with which the changes are made is truly remarkable. Over a period of weeks, the average number of cans hoisted through a single shaft is 850 per eight hours. The full time of the shift is not available for hoisting alone, as men and materials pass to and from the mine via the same route. During the actual hoisting time, an average of two cans per minute is maintained, the hoisting distance being 350 feet.

The hoisting units are located on the floor of the hoisting derricks, about 40 feet above the shaft collar. At the Hartley mine two types of hoisting units are used. One is an electric-driven unit of the design most commonly used throughout the district. This consists of an electric motor connected through a flexible coupling to the pinion which drives the drum gear. Hoists of this type are in most cases powered by a 125-hp. motor.

The electric power schedule in vogue in the Tri-State district imposes a charge of \$2 per horsepower per month on all motors used in shaft-hoist service. On a 125-hp. hoist, this charge amounts to \$250 per month and is added to the energy charge. This brings the total charge per month for operating a hoist of this type, at full capacity, to about \$500. With a view to cutting down this hoisting cost, a gas-engine driven hoist has been developed at the Hartley mine. This consists of a 120-hp., vertical-cylinder, Diesel-type gas engine direct-connected by a flexible coupling and clutch to the hoist drum. The general details of this unit are shown in Figure 7. This unit is very satisfactory and can be operated at less than one-third the cost of operation of the electric driven unit. It is also fully as fast and flexible. The engine is equipped with a compressed-air starter, and in case of emergency the engine can be operated on air. This is an important safety feature in event that the gas-supply main should be ruptured while the men are being hoisted. During the lowering of men and heavy loads, the hoist can be run against the compression of the engine, which relieves to a great extent the strain on the brake band and mechanism. The cost of this unit is about one and one-half times that of the electric-driven type, but this is soon compensated for by the saving in operating cost.

All hoisting is done with 5/8-inch steel cable of the non-spin type. These cables are closely watched, and at the first sign of wear or stranding they are replaced. The average life of a cable on this service is from 50,000 to 60,000 tons of ore hoisted and the cable cost runs from one-tenth to two-tenths of a cent per ton hoisted.

The contents of the cans drop into a surface hopper or bin from which the material is drawn into cars and transported to the milling plant. Numerous mines throughout the district are making use of steel construction in bins and derricks. Figure 8 shows a steel hopper and derrick such as is used at the Hartley mine. This is the first round field hopper that was constructed in the Tri-State district. It is equipped with skid members so that it can be moved to other shaft sites on the property if desired.

#### Wage and Contract System

The only contract workers at this mine are the hand shovelers and hoist operators. Shovelers work on a direct contract basis, receiving from 12 to 14 cents per can for loading and delivering to the mine haulage track. Hoist operators receive a base rate of \$5 per day, and in addition thereto they receive 1 cent per can for all cans hoisted per shift over a count of 600. This bonus is figured on the weekly average and not by the day. In most cases the hoist operator divides this bonus with the tub hooker, since speed can only be attained with close cooperation between the two.

This company also adheres to the sliding wage scale with respect to the market value of zinc concentrates. This scale is based on a concentrate value of \$40 per ton. For each change of \$5 above or below this value, the wages are raised or cut 25 cents per day on all day labor and  $\frac{1}{2}$  cent per can on hand loading. The working shift constitutes eight hours. A list of the base scale follows:

|                        |        |
|------------------------|--------|
| Machine operators..... | \$4.75 |
| Machine helpers.....   | 4.25   |
| Blacksmiths.....       | 6.00   |
| Trammers.....          | 4.00   |
| Powdermen.....         | 5.00   |
| Roof trimmers.....     | 4.25   |
| Cagers or bumpers..... | 4.00   |
| Tub hookers.....       | 5.00   |

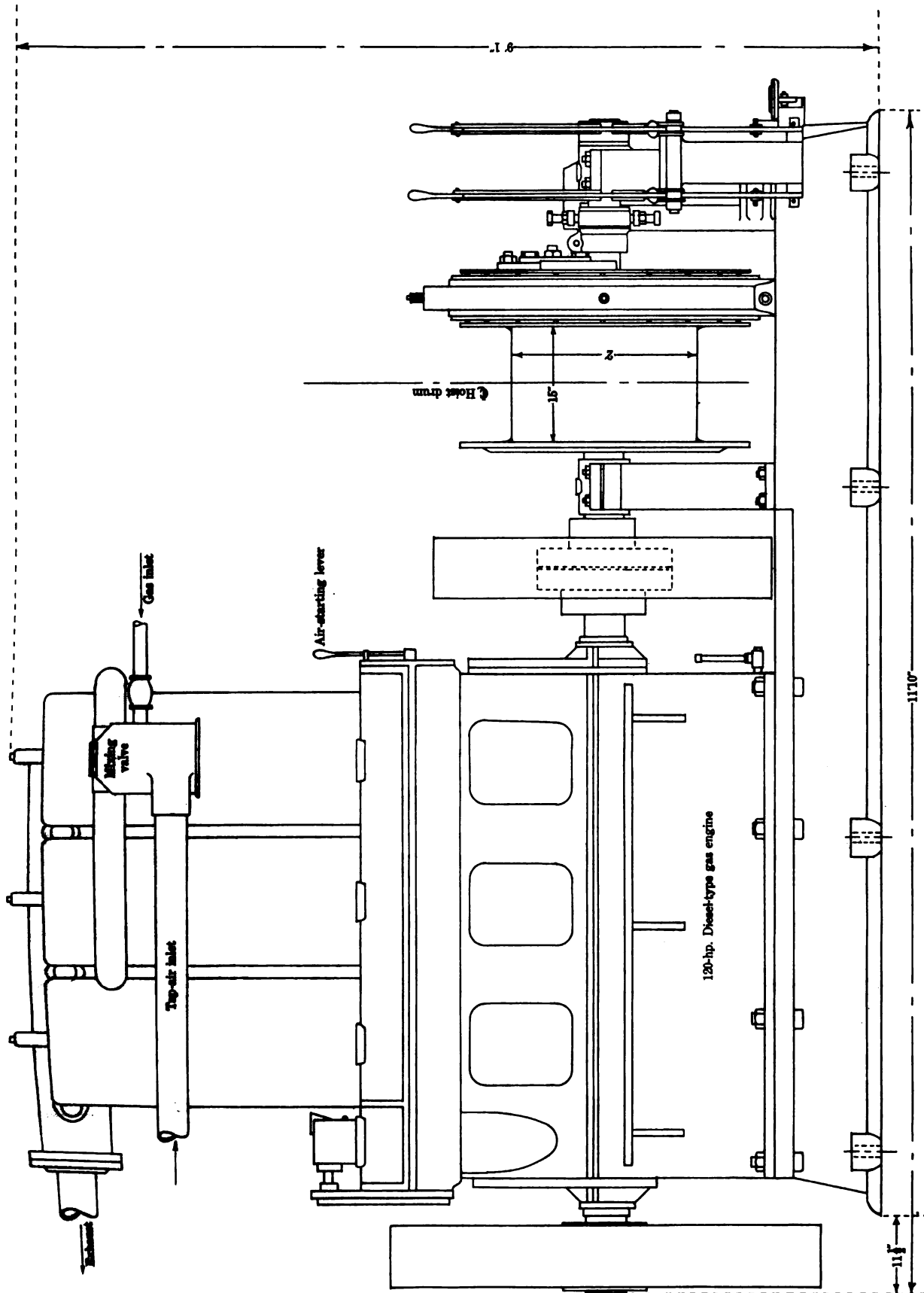


Figure 7.- Gas-engine driven hoist

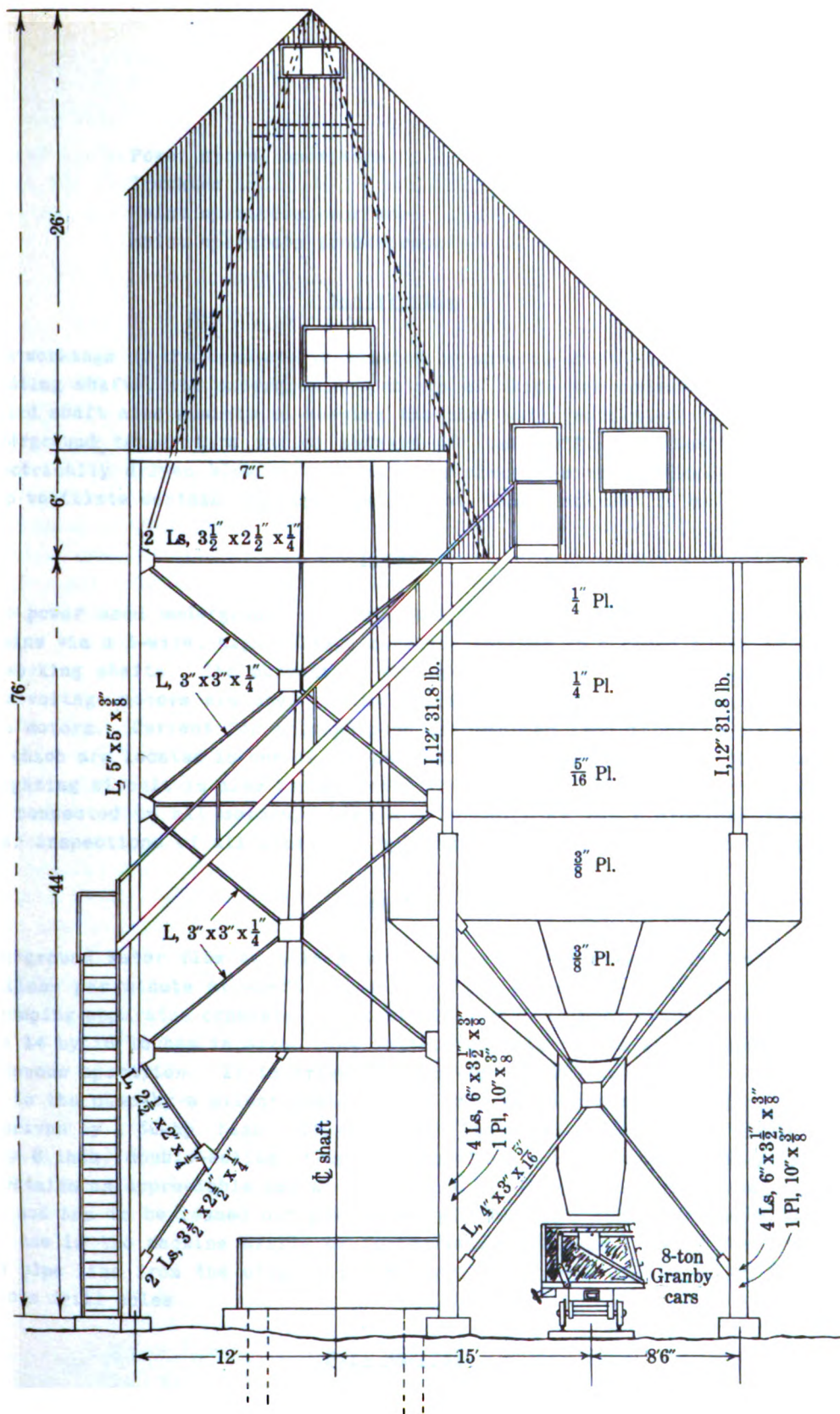


Figure 8.- Steel field hopper and derrick, capacity 400 tons

|                                    |      |
|------------------------------------|------|
| Power shovel operators.....        | 5.00 |
| Trackmen.....                      | 4.50 |
| Hoist operators (surface).....     | 5.00 |
| Hoist operators (underground)..... | 4.50 |

### Ventilation

The main workings of the mine are ventilated by natural draft, which circulates through the two operating shafts, the underground openings of which are connected by a ventilation drift. A third shaft also assists in keeping the mine well ventilated.

The underground temperature varies between 60° and 70°F. with but a small seasonal change. Electrically driven blowers are at times placed on the surface over cased drill holes to help ventilate certain headings that are at times inclined to have dead air.

### Power

Electric power used underground on pumps and power shovels amounts to 110-hp. This reaches the mine via a 3-wire, high-voltage circuit, encased in a conduit, which is run down each of the working shafts. The current of this power circuit is 2,200 volts, 3-phase, 25 cycles. High-voltage motors are used on the pumps only, the power shovels being equipped with 220-volt motors. Current for this purpose is obtained from three 15-k.v.a. step-down transformers which are located in one of the pump chambers. In addition to the power circuit a 110-volt lighting circuit is also brought down the shaft in a conduit. Safety and control apparatus is connected to all motors, which are housed over for protection from dust and drip. Regular inspections of all lines and apparatus are made by a competent electrician.

### Pumping

The underground water flow at this mine varies at the different shafts, amounting to about 700 gallons per minute at shaft 6 and about 150 gallons per minute at shaft 8. At shaft 6 the pumping apparatus consists of two single acting triplex pumps, one 8 by 10 inches and the other 14 by 16 inches in size. The latter constitutes the main pumping unit and is kept in continuous operation. It is driven by a 50-hp., 2,200-volt, 475-r.p.m. motor which is connected to the pump by a silent-chain drive. The smaller pump is used as an emergency unit and is driven by a 30-hp. high-voltage motor. The small water flow at shaft 8 is handled by a 5 by 6 inch, double-acting, triplex pump which is driven by a 15-hp. motor. The mine water contains an appreciable amount of iron oxide; this builds up on the inside of the pump columns and has to be reamed out periodically. For this reason the mine water is not suitable for use in the machine drills or for drinking purposes. Water for these uses is brought by a pipe line from the city of Baxter Springs, Kans., and is piped into the mine through various drill holes.

### Fire Hazards

The workings present no fire hazards, since practically no timber is used underground and no gas pockets are encountered in the course of mining. On the surface, all vegetation is removed for a distance of 100 feet from the shaft collar and the ground is covered with coarse mill tailings. This precludes any danger of grass fires reaching the shaft structure. All shaft derricks are equipped with fire extinguishers and safety cans for oily waste and rags. All wooden derricks have a ladder extending from a window directly back of the hoist

operator's position to the ground, to be used as an emergency exit should the stairway at any time be cut off. A telephone system connects the main office with the mine workings. The regular city fire department of Baxter Springs answers all calls to the Hartley mine, which makes ample fire-fighting equipment available.

#### Blacksmith Shop

All drill steel is redressed in a surface shop. At each shaft station there is a drill-steel rack for both the sharp and the dull steel. At certain regular intervals during the shift, dull steel is exchanged for sharp, the steel being hoisted in round sheet-steel cans 18 inches in diameter and 12 feet long. These cans have a bail in one end to which the hook on the hoist cable is attached. One man on the surface tends to all steel delivery between the shop and the various shafts. For this purpose a 4-ton Plymouth gasoline locomotive is used, the cans of steel being hauled on low flat cars build for this purpose.

The drill shop contains two No. 50 Leyner drill sharpeners, two gas heating furnaces, and one gas reheating furnace, together with tempering vats, grinders, etc. Connected with this department is a completely equipped machine shop, where repair work of any nature can be done. One heating furnace, sharpening machine, and reheating furnace are in constant use; the other unit is reserved for emergency use.

The track system in and out of the shop is so arranged that dull steel arriving from the mine does not interfere with sharp steel returning. From the time that the drill steel leaves the mine until it returns, it is not at any time turned end for end, its passage through the shop being in a straight line. This adds greatly to the efficiency of the sharpening crew. Three men compose the crew, one each on the heating furnace, sharpening machine, and reheating furnace. The men on the heating furnace and sharpening machine alternate about every hour, and in this way the crew of three men have resharpened and retempered as many as 740 drill bits per 8-hour shift. The daily average, however, is 550 drill bits. The drills at this mine are subjected to severe duty, as the rock being drilled consists of 95 per cent of flint and contains numerous pockets and fracture planes. Under average conditions a sharp steel will just run out its change length of 2 feet. The average steel breakage amounts to 2 per cent.

Machine drills are repaired and put in order in a drill repair shop in charge of a drill mechanic. This man is responsible for the upkeep of all drills and makes daily trips through the mine to see that the machines are getting the proper treatment and lubrication. Records of repairs are kept for each individual machine. When repairs are made, the drill operator is given a slip, showing just what was done and the cost of the work and new parts. This has been found to be well worth while, as it teaches the drill runner the cost of the wearing parts of his machine, the life of which he has more or less the power to control. Machine-drill data taken over a period of eight months is as follows:

|                                               |            |
|-----------------------------------------------|------------|
| Machine shifts worked.....                    | 3,257      |
| Holes drilled, total.....                     | 21,779     |
| Holes drilled per shift.....                  | 6.7        |
| Footage drilled, total.....feet               | 196,112    |
| Depth per hole, average.....do.               | 9.0        |
| Ore broken, total.....tons                    | 202,839    |
| Ore broken per machine-shift, average.....do. | 62.2       |
| Cost of drill upkeep, total.....              | \$1,765.22 |
| Upkeep cost per machine-shift.....            | \$0.5419   |

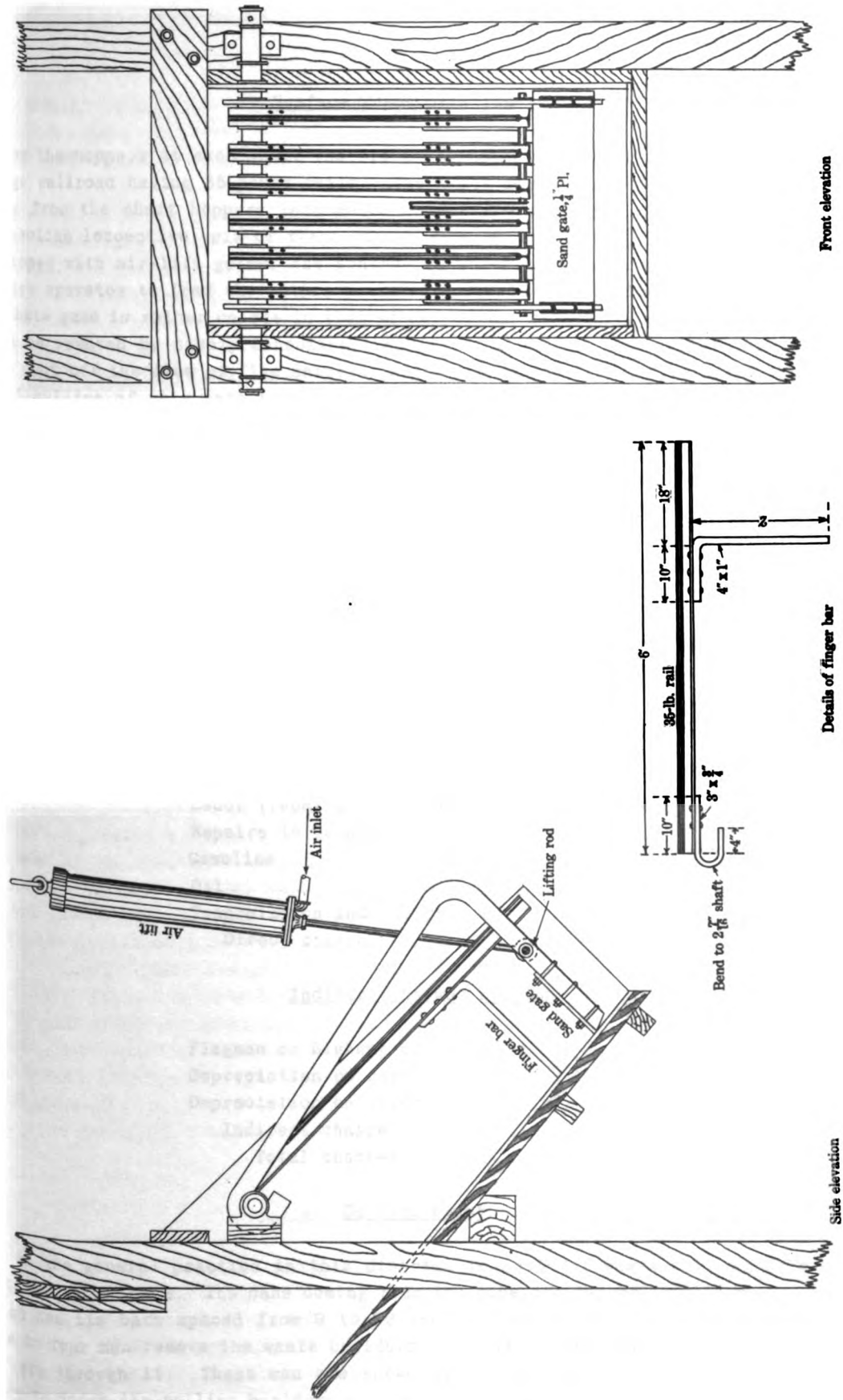


Figure 9.- Hartley chute gate

Surface Transportation

From the hoppers at each shaft the ore is transported to the crushing plant over a 36-inch gage railroad having 35-pound rails. The track layout is shown in Figure 2. The ore is drawn from the shaft hoppers into 8-ton capacity Granby-type cars which are drawn by a 7-ton gasoline locomotive, six of these cars making up the train. The chutes of all hoppers are equipped with air-lift gates, the control of which extends down the track, allowing the locomotive operator to load the entire train without leaving the locomotive cab. The design of the chute gate is rather unique in that if any of the individual finger bars become broken they can be removed by simply unhooking them from the shaft. The gate is also constructed so as to shut off the flow of fine material after the run of larger pieces has been retarded. A general outline of this gate is shown in Figure 9.

At the crushing plant the train passes over a pit, where the cars automatically discharge their contents as the train advances. All cars are equipped with roller bearings and are of steel construction throughout. The direct transportation charge per ton of ore hauled from the various shafts to the crushing plant amounts to about 1 cent, the average haul being 2,600 feet.

Details of transportation charge

Period covered: 6 months      Ore hauled: 121,762 tons

Direct operating charges per ton

|                                  | <u>Cents</u> |
|----------------------------------|--------------|
| Labor (operator).....            | 0.756        |
| Labor (repairs on track).....    | .039         |
| Repairs to locomotive and cars.. | .049         |
| Gasoline.....                    | .271         |
| Oil.....                         | .012         |
| Transmission and cup grease..... |              |
| Direct charge.....               | 1.155        |

Indirect charges per ton

|                                  |             |
|----------------------------------|-------------|
| Flagman on highway crossing..... | 0.446       |
| Depreciation on cars.....        | .275        |
| Depreciation on locomotive.....  | <u>.242</u> |
| Indirect charge.....             | 0.963       |
| Total charges.....               | 2.118       |

Sorting Plant

It is the general practice in this district to sort out waste on a grizzly placed on top of the shaft hoppers. The cans coming from the mine are dumped on this heavy rail grizzly, which has its bars spaced from 9 to 12 inches, depending upon the nature of the ore. From one to four men remove the waste boulders from the grizzly and break the oversize boulders of ore through it. These men are known as "screen apes," and the alacrity which is necessary to dodge the rolling boulders as they come from the can truly justifies this title. The condition under which these men work is anything but good, and the output per man is con-

sequently small. Study of this problem and much test work indicated many advantages in favor of a systematically arranged sizing and hand-picking plant. Such a plant was constructed in 1928, and its operation has yielded results fully up to all expectations. Figure 10 is a general flow sheet of this plant.

From the receiving pit the ore passes by gravity to a 36 by 18 inch Blake-type rock breaker. This breaker is situated in a pit, 23 feet below the surface and has a discharge opening of 4 inches. The product of this breaker goes to a 24-inch incline belt conveyor which conveys the material to the surface and up to the head of the sorting house. Here, the material goes onto a 2-deck vibrating screen. The upper deck of this screen has openings 3 inches square and the lower deck openings  $1\frac{1}{2}$  inches square. The undersize from the lower deck goes to a small storage bin, from which it is taken by a 20-inch incline belt conveyor to the main mill storage bin. No sorting is attempted on any material that is less than  $1\frac{1}{2}$  inches in size. The oversize from each screen deck goes to an individual washing screen where the particles pass under a series of water sprays. The product of each of these washing screens goes to a horizontal picking belt, 36 inches wide and 22 feet long. From three to four men are stationed on each side of the two picking belts, and it is their duty to remove all of the mineralized particles. Note that in this case, ore is being picked from the waste and the discharge from the ends of both picking belts is rejected as a coarse tailing. The reject passes to a 20-inch incline belt conveyor which serves as a stacker for this waste material. The ore removed from the picking belts is conveyed to a secondary breaker, which has a 2-inch discharge setting. The product of the breaker goes to the same belt conveyor as the screen undersize, the two products being conveyed to the main mill storage bin. The mill bin is of the round hopper type, is constructed of sheet steel, and has a live capacity of 1,000 tons. All water used in washing the screen oversize is collected and sent by launder to the first mill elevator, so that in this way all fine mineral washed off is recovered. By this hand-sorting method from 40 to 50 per cent of the tonnage hoisted is eliminated from the mill circuit and is rejected in the coarse sizes. The zinc tenor of the coarse waste material runs from 0.3 to 0.4 per cent of zinc sulphide, whereas the tailing of the concentrating plant runs from 0.6 to 0.8 per cent of zinc sulphide. The cost of the hand-picking operation, based on the tons that go to the picking belts, is from 9 to 11 cents per ton. The advantages of this system at this particular mine are many, and include (1) low capital investment per ton of material rejected, (2) lower metal content of combined tailings, (3) lower cost of treatment per ton, and (4) enriched feed to concentrating plant.

There is a further advantage which is gained from the sale of the coarse reject as commercial stone. A plant has been built which reclaims the coarse waste, recrushing and sizing it to any specifications that the market may demand. The product of this stone plant is delivered to standard-gage railway cars by a 20-inch belt conveyor. The profit from this crushed stone amounts to more than the total cost of the picking operation. However, the stone plant is conducted as an entity and its figures are not included in those of mining and milling.

#### Safety Methods and First Aid

The company maintains a safety engineer who inspects daily all points where work is being done, both on the surface and underground. There is also a safety organization which is known as the Workman's Safety Council. This is made up of five employees, two representing each mine crew and one the surface and mill crews. These men serve on the council for a period of four weeks and at the end of this period they each appoint a successor from their respective crews. During the period that a man is on the council, he is given a full day's instruction in first-aid treatment at the United States Bureau of Mines clinic at Picher.

Okla. Council meetings are held once each week with the safety engineer acting as chairman. At these meetings subjects pertaining to safety that have come up during the week are discussed. Proposals and suggestions received from an employee's question box are read and considered at each council meeting.

All employees are required to have passed a physical examination at the United States Bureau of Mines clinic and to have a rating of C grade or better before they are put to work. The result of this safety work has been very gratifying and the men themselves take a keen interest in its promotion.

Group life insurance is carried on all employees that have been in service six months and is periodically increased with the employee's length of service. At the end of six years it amounts to \$2,000. This insurance is presented to the employee, free of cost, as an expression of goodwill and cooperation.

#### SUMMARY OF COSTS

Hartley mine of The Interstate Zinc and Lead Co.

Period covered: Six months

Tons of ore hoisted during period: 180,212 Mining method: Open rooms with pillar support.

#### Underground costs per ton of ore hoisted

|                                                          | Labor    | Supervision | Compressed-<br>air drills<br>and steel | Power    | Explosives | Other<br>supplies | Total    |
|----------------------------------------------------------|----------|-------------|----------------------------------------|----------|------------|-------------------|----------|
| Development <sup>1</sup> .....                           | -        | -           | -                                      | -        | -          | -                 | -        |
| Mining.....                                              | \$0.3018 | -           | \$0.0781                               | \$0.0307 | \$0.1502   | \$0.0113          | \$0.5721 |
| Transportation.....<br>(underground)                     | .1123    | -           | -                                      | .0298    | -          | .0096             | .1517    |
| General underground<br>expense.....                      | .0261    | \$0.0250    | -                                      | -        | -          | .0117             | .0628    |
| Surface expense.....<br>(applicable to under-<br>ground) | .0415    | -           | -                                      | -        | -          | -                 | .0415    |
| Total.....                                               | 0.4817   | 0.0250      | 0.0781                                 | 0.0605   | 0.1502     | 0.0326            | 0.8281   |

1 - No development work was done during this period.

## SUMMARY OF COSTS IN UNITS OF LABOR, POWER, AND SUPPLIES

Hartley mine

6-month period

Tons of ore mined and hoisted: 180,212.

Mining method: Open rooms with pillar support.

---

|                                                     |        |
|-----------------------------------------------------|--------|
| A. <u>Labor (Man-hours per rock ton):</u>           |        |
| Breaking (drilling and blasting).....               | 0.229  |
| Shoveling:                                          |        |
| Hand only.....                                      | 0.218  |
| Mechanical.....                                     | 0.160  |
| Average.....                                        | 0.198  |
| Haulage and hoisting.....                           | .080   |
| Supervision.....                                    | .033   |
| General (including steel sharpening).....           | .133   |
| Total underground labor.....                        | 0.673  |
| Average tons per man-shift (underground).....       | 11.88  |
| Average tons per man-shift (surface).....           | 198.50 |
| Labor, percentage of total cost.....                | 58.20  |
| B. <u>Power and supplies per rock ton:</u>          |        |
| Explosives, 40 per cent ammonia (lbs. per ton)..... | 1.12   |
| Power (horsepower-hours per ton):                   |        |
| Air compression.....                                | 2.43   |
| Hoisting.....                                       | 1.73   |
| Pumping, loading, etc. ....                         | 1.50   |
| Total.....                                          | 5.66   |
| Supplies and power, percentage of total cost.....   | 39.00  |

---

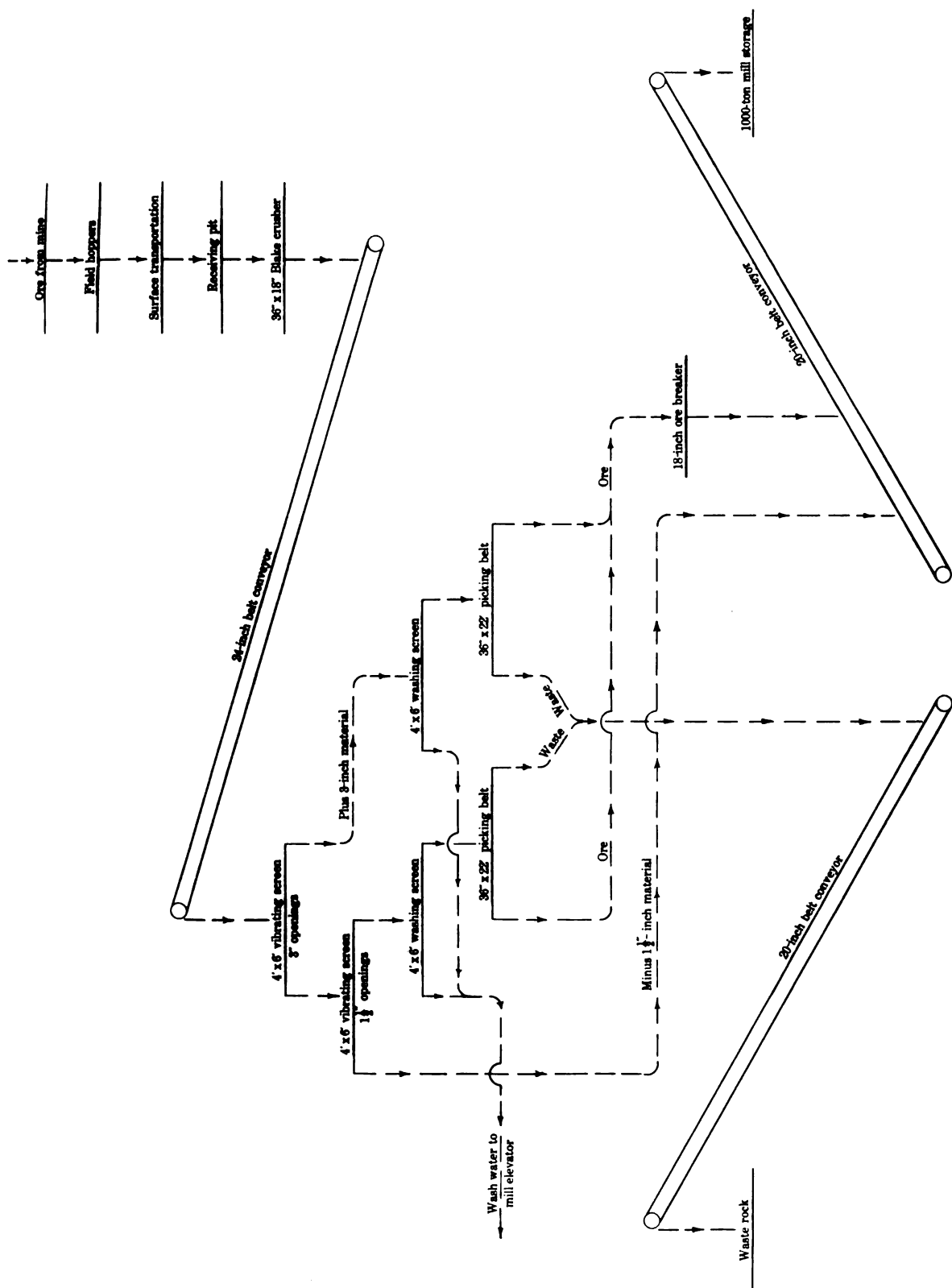


Figure 10.- Flow sheet of sorting system, Hartley mine